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ABSTRACT

A major concern of science educators is the lack of talented females selecting science careers. In spite of attempts during the past few decades to create equality in all facets of life in the United States, many sexual stereotypes persist. The research presented here is designed to examine the relationship of sex to the relevant factors influencing the decision to choose a college major in the technical sciences. Data from students in the High School and Beyond sophomore cohort who had participated in surveys in 1980, 1982, 1984, and 1986 (n=188) were analyzed and a path model was constructed. While noticeable gender differences did emerge in this study, there was a very small direct effect of gender on the dependent measure of science major. Many of the strong paths showed similar results for both sexes, for example, the path leading from family background through ability, achievement, and advanced courses, to college major. Separating the analyses by sex helped to point out some interesting path differences. The most interesting difference involved the path for females--from self-efficacy through science and mathematics attitudes, to advanced courses, and then on to college major. The same path was virtually absent for males. A list of 16 references is included. (CW)

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Gender Differences in Selecting Undergraduate Science Majors

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Introduction

A major concern of science educators is the lack of talented females selecting science careers. In spite of this nation's attempt during the past few decades to create equality in all facets of American life, many sexual and ethnic role stereotypes persist. Blacks and Hispanics remain educationally underprivileged forcing, the poverty cycle to continue. Women do not seem to have the same opportunities as men in certain fields of study. The problem facing educational and social researchers is that these barriers to women are often more subtle than those confronting ethnic groups.

Deboer (1984) discovered that women in a highly selective undergraduate institution took significantly fewer science courses than men, even though they outperformed men in the science courses in which they were enrolled. Women were able to do the work, but for some other reason they chose to take fewer science classes. Previous studies have suggested that women have a lower innate ability in mathematics and spatial reasoning (Stafford 1961, Graybill 1975, Benbow and Stanley 1980), but others (Hyde 1981) have demonstrated that even if these genetic differences are present they account for only a minor portion of the total variability. When investigating students who pursue science careers, we are dealing with a small fraction of the population, regardless of gender. As the findings of this study and others (Deboer, 1984, Levin, et al. 1984, Handley, et al. 1984) have indicated, the problem does not seem to lie in the area of science achievement or having girls enroll in high school science courses, but in developing the attitudes that will lead to females choosing science careers.

Steinkamp and Maehr (1984) conducted a meta-analysis of motivational orientation and academic achievement in science. They found that small but consistent differences favoring males in achievement and motivation were

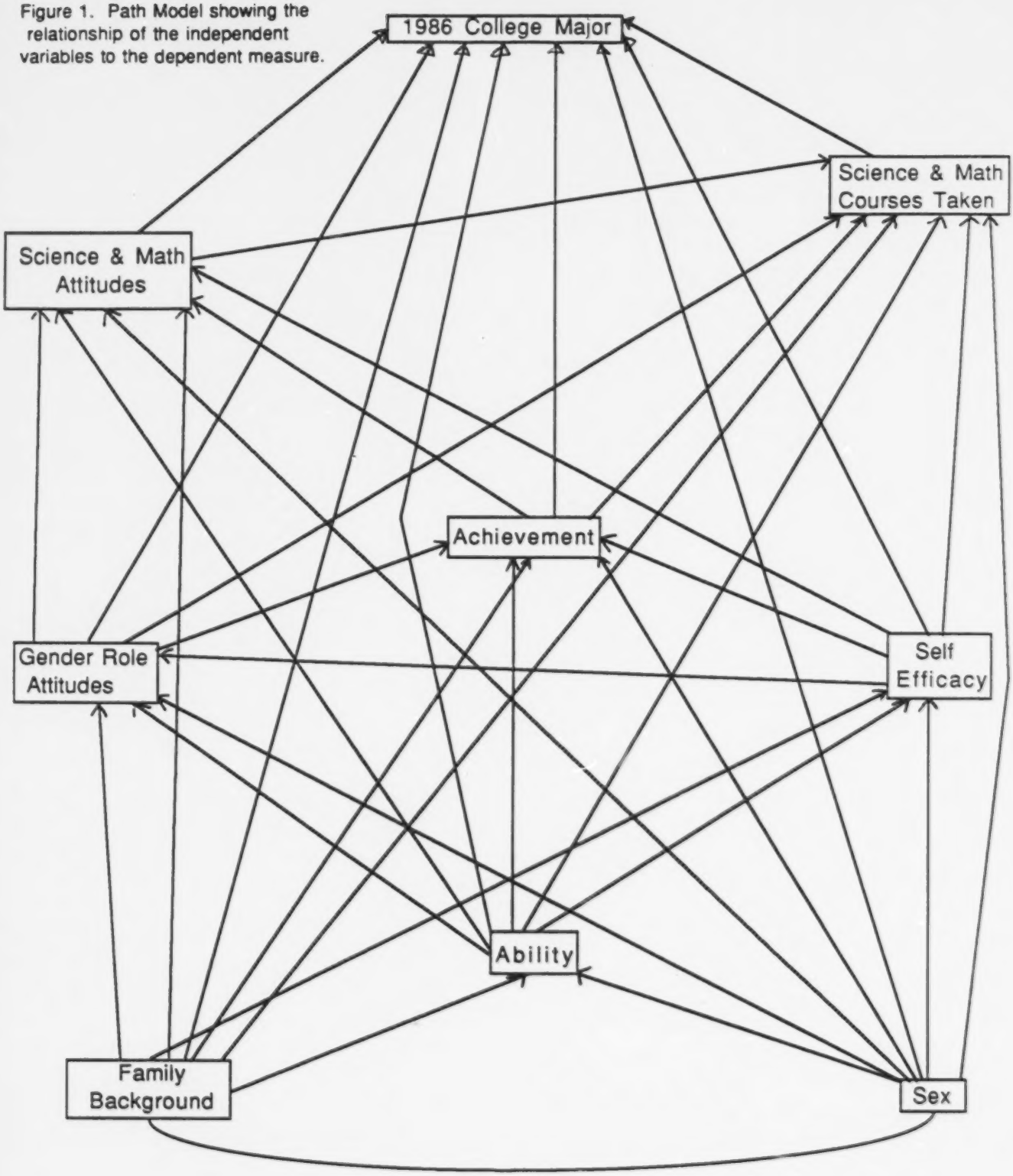
common in almost all studies. Their analysis illuminated some interesting differences in motivational levels across science subject areas. They found that girls tended to have higher motivational orientations in biology and chemistry, whereas boys had higher scores in physical science motivation. It was unexpected to find that girls motivational orientation was higher in chemistry, a physical science. Steinkamp and Maehr (1984) postulated that this physical science/chemistry motivational difference might exist because chemistry is not easily learned outside of the classroom, while general and physical science principles, "can be learned outside the classroom, and boys have more opportunities to develop positive attitudes in those areas" (Steinkamp and Maehr 1984). If this is the case, boys should have higher motivational scores on biology, probably the most common science area taught and appreciated outside the formal classroom. The research presented here is designed to examine the relationship of sex to the relevant factors influencing the decision to choose a college major in the technical sciences.

Logic of the Model

The aim of this study was to develop a model that would identify the strongest predictors for high school students to become undergraduate science majors. Once the initial model was tested, the data were split to look at males and females separately. I believed that if I could discover why women became science majors, educators might be able to use this information to encourage greater female participation in science. I elected to use the same model to examine why men chose science as their major field of study. By comparing the path analyses of men and women, the predictors for female choice of science majors would become clearer.

The model developed in this study is depicted in Figure 1. The path model is a pictorial representation of the theories and hypotheses driving

Figure 1. Path Model showing the relationship of the independent variables to the dependent measure.



this research. The direction of the arrows in the model implies that if a causal relationship between the two variables exists, it is in the direction specified. The choices of the variables for the model and the direction of the arrows are based upon previous research, educational and psychological theory, temporal relationships, and logic. In obvious cases (especially among exogenous variables) where no direction of causality could be implied, only correlation coefficients were reported.

The longitudinal High School and Beyond data were collected by the National Center for Educational Statistics to study a variety of educational, vocational, and personal characteristics of young people as they progressed from high school through post-secondary education and/or careers (National Opinion Research Center, 1987). Unlike the earlier High School and Beyond (HSB) surveys, the 1986 questionnaire (third follow-up) asked the students to write-in their particular field of study. This allowed the National Center for Education Statistics to more accurately classify each student's college major, resulting in a categorization of approximately 500 specific college majors.

From the available college majors, this study concentrated on those students who fit into one of the following six groups: social sciences, psychology and educational research, natural resources and agriculture, life sciences, engineering and applied sciences, and physical sciences. These six groups are ranked on a scale ranging from least technical and more humanistic to most technical and least humanistic.

Science and math attitudes is a more loosely defined composite variable. It is an attempt to assess the student's view of science and math, at the time of the survey and in the future. It was again hypothesized that students who take advanced science and math courses in high school and later go on to

become science majors in college will have positive attitudes. I decided to place this variable closer to the dependent variable than the achievement composite, because achievement has an impact on the way students feel about school and science in particular.

I was interested in the role that self-efficacy plays in the choice of science majors. Many studies (Handley et. al. 1984; Doran et. al. 1978; Jacobowitz 1983, and Peterson et. al. 1980) have described the role that self-cóncept plays in science achievement, but most have focused on student's self-concept in science. Although this is useful, most of these studies have indicated that science achievement is a strong predictor for the student's self-concept in science. One of the aims of this study was to examine the student's general feeling of self-efficacy, to determine if a strong feeling of self-worth and an internal locus of control could be used as predictors of undergraduate science majors.

Placement of the most exogenous variable, family background, is based primarily on temporal reasons and many studies demonstrating the effects of family income upon ability and school achievement (White 1982).

Ability and achievement were included in the model because of their obvious relationship to scientific careers. Technical and laboratory science careers usually require at least a four year college and are often considered intellectually demanding college majors. It was hypothesized that the exogenous variables would have direct and indirect effects upon achievement and ability, which in turn would have direct and indirect effects on the dependent measure of college major.

The closest independent variables to the dependent measure of college major is advanced science and math courses taken. It is generally expected that high school students planning to study science in college will select

advanced courses in high school. Although many high school students do not know what their college major will be, it was hypothesized that many future scientists make this decision by the end of their high school years. Because most of these advanced courses are elected during the last two years of high school, I expected this variable to produce a strong direct effect upon college major.

Variables

The following variables were either selected directly from the HSB sophomore cohort data set or created from existing HSB variables.

College Major. This dependent measure was derived from the 1986 survey. College majors or fields of study in the "sciences" were grouped into six general categories, ranging from the traditional technical sciences such as physics and mathematics to the less well defined social sciences. Originally this model had been developed using only two groups; technical and non-technical sciences, but the overlap between many of the majors led me to develop a finer and more representative scale. Certain majors which were originally grouped into "hard or technical" sciences such as 'Natural resources' studies, clearly belong in a middle grouping. The same is true for majors in psychology and educational research They have traditionally been considered "soft or non-technical" sciences, but with the present emphasis on quantitative studies, the distinction between technical and non-technical sciences becomes less clear. The classification of majors is as follows:

Group 1 -Social sciences, i.e. sociology, anthropology, political science.

Group 2-Psychology and educational research.

Group 3-Natural resources, agriculture, and food sciences.

Group 4-Life Sciences, i.e. biology, ecology, botany, zoology, pre-med.

Group 5-Engineering and Applied sciences

Group 6-Physical sciences, i.e. physics,chemistry, geology, math, etc.

Advanced science and math courses taken. This was a composite variable computed by adding one point for a course taken in each of the following subjects (one point per subject) physics, chemistry, algebra 2, trigonometry, and calculus. The variable was computed from the first follow-up (1982) survey. Values ranged from 0-5.

Science and Math Attitudes. This composite was the mean of the z-scores of six items from the data set. The following questions, asked of 1980 sophomores, designed to determine how the student felt about math and science were included in this composite: "Math will be useful in my future", "Math is interesting to me", "I am usually at ease in Math class", "Math assignments usually make me feel tense", "Number of Math classes you plan to take during the last two years of high school", and "Number of science classes you plan to take during the last two years of high school". Steinkamp and Maehr (1984) stated that measures of motivation and attitudes need only be indicative of an approach/avoidance tendency, as is the case with the items used to form this composite.

Achievement. The achievement composite was weighted to over-represent student's math and science knowledge. Z-scores were created for the number correct on the math test #1, math test #2, the science test (weighted twice) the reading test, and the student's self report of grades so far. These standardized scores were then combined to form the composite. The student's self-report of grades so far was included in this composite because grades are a useful measure of achievement over a longer period of time than one standardized test, but because it was a self-report it was only weighted one-sixth. The achievement composite was computed using the 1980 achievement tests and the 1982 report of high school grades.

Gender Role Attitude. The gender role composite was composed of questions intended to assess the students' feeling about traditional sex roles. The following questions were asked in the sophomore (1980) and senior (1982) high school years: (a) "A working mother of pre-school children can be just as good a mother as the woman who doesn't work;" (b) "It is usually better for everyone involved if the man is the achiever outside the home and the woman takes care of the home and family;" and (c) "Most woman are happiest when they are making a home and caring for children." These questions were Liekert-type items, and a mean of the six responses (3 questions x 2 years) was computed to form the gender role composite for each student.

Self-Efficacy. The self-efficacy composite was based on nine self-concept and locus of control items asked in the base year (1980) survey. I only used questions that refer to the individual student (I, my, or me). Responses were recoded so that an internal locus of control and a high self-concept received high values. These were all Liekert-type items. The following items were included in this composite: "I take a positive attitude toward myself", "I feel I am a person of worth", "Every time I try to get ahead, somebody or something stops me", "On the whole, I am satisfied with myself", "What happens to me is my own doing", "At times I think I am no good at all", "When I make plans, I am almost certain I can make them work", and "I feel I do not have have much to be proud of", "I am able to do things as well as most other people." Z-scores were created from these items and means were computed only if the student had valid responses for 6 or more of the individual items.

Ability Composite. This composite was designed to reflect the students innate ability or abilities in areas generally not covered in school. The

vocabulary sub-test (1980) was used as the ability variable. The correlation between vocabulary skills and general intelligence has been well documented (Sternberg 1984); for this reason, it was used as the ability variable and not in the achievement composite.

Family Background Composite. A possessions composite was formed from the five yes or no items: Do you have a place to study, encyclopedia, typewriter, 50 or more books, and a personal calculator. Then the mean of the standardized scores of base year data (1980) for family income, mother's education, mother's occupation, father's education, father's occupation, and possessions was computed for each student. This is similar to the socioeconomic status (SES) composite already computed by the National Center for Educational Statistics except that it includes mother's occupation.

Sex. This dummy variable was coded so that the value for males was equal to 0 and females equal to one. This variable was not included in the model when the path analysis was conducted for each sex separately.

Methods

Longitudinal data from the HSB sophomore cohort (high school sophomores in 1980) were used. Students in this cohort were selected through a two-stage, stratified probability sample with schools as the first stage sampling units and students as the second stage. There were 1015 schools selected for the sample, and 36 seniors and 36 sophomores were randomly selected within each school. In those schools with fewer than 36 seniors and/or sophomores, all eligible students were included in the sample. Follow-up surveys were conducted in 1982, 1984, and 1986.

The dependent variable, college major, was taken from the 1986 follow-up survey when a majority of the 1980 college-bound sophomores would have been college seniors. Only those students who participated in all four surveys and

whose college major was in one of the six general college major groups, were selected for this study. A sample size of 447 students resulted after these selection procedures. Listwise deletion of missing values was used during the regression procedures, producing a final sample of 188 students. All statistical analyses were performed using the SPSSX (SPSSX, Inc., 1988) and an IBM 3090-180E computer.

All analyses were conducted with the HSB sampling weights in effect. In order to preserve an accurate but proportionally correct sample size, the weight for all four surveys was divided by a mean weight to yield the weighting measure that was used in this study.

The model in Figure 1 was tested using a series of ordinary least-squares multiple regression equations. First, the dependent variable was regressed on all independent variables. The resulting regression coefficients represent the direct effects of each independent variable upon the dependent measure. To discover the indirect effects, each independent variable was then used as the dependent variable, based on their order in the model (i.e. proximity to the dependent variable). After a variable was used as the dependent measure, it was not used in the regression analysis again. All variables were eventually used as the dependent variable except the most exogenous, family background.

Results

Means, standard deviations, ranges, and intercorrelations for the nine variables are presented in Table 1. Statistically significant intercorrelations (alpha=.05) were found among all variables except between college major and self-efficacy, and between college major and achievement. The strongest correlations were found among family background, achievement, ability, and science and math courses taken. The gender role variable showed

Table 1. Means, standard deviations, ranges, and Pearson correlation coefficients.

Variable	M	SD	R	1	2	3	4	5	6	7	8	9	
1. Sex	.526	.499	0-1	1.00									
males	- - -												
females	- - -												
2. Family Background (1980)	.140	.627	-1-2	-.04*	1.00								
males	.169	.637	-1-2	- - -	1.00								
females	.113	.618	-1-2	- - -	1.00								
3. Ability (1980)	11.12	4.40	0-21	-.05*	.33*	1.00							
males	11.34	4.40	0-21	- - -	.34*	1.00							
females	10.93	4.39	0-21	- - -	.33*	1.00							
4. Self Efficacy (1980)	0.00	.555	-3-1	-.08*	.13*	.13*	1.00						
males	.048	.542	-2-1	- - -	.13*	.16*	1.00						
females	-.042	.562	-3-1	- - -	.12*	.11*	1.00						
5. Gender Role (1980-82)	.015	.630	-2-2	.32*	.14*	.18*	.03*	1.00					
males	-.205	.562	-2-2	- - -	.15*	.16*	.03*	1.00					
females	.198	.625	-2-2	- - -	.18*	.26*	.07*	1.00					
6. Science & Math Attitudes (1980)	-.004	.548	-1-1	-.07*	.20*	.24*	.18*	.06*	1.00				
males	.035	.542	-1-1	- - -	.23*	.30*	.19*	.10*	1.00				
females	-.040	.552	-1-1	- - -	.18*	.19*	.16*	.10*	1.00				
7. Science & Math Courses (1982)	1.65	1.59	0-5	-.10*	.32*	.43*	.16*	.11*	.49*	1.00			
males	1.82	1.68	0-5	- - -	.32*	.45*	.17*	.12*	.51*	1.00			
females	1.50	1.50	0-5	- - -	.32*	.41*	.14*	.19*	.47*	1.00			
8. Achievement (1980-82)	.014	.969	-2-3	-.07*	.32*	.73*	.16*	.13*	.38*	.58*	1.00		
males	.083	1.00	-2-3	- - -	.32*	.73*	.18*	.13*	.44*	.60*	1.00		
females	-.046	.935	-2-3	- - -	.31*	.73*	.12*	.21*	.32*	.55*	1.00		
9. College Major (1986)	3.55	1.49	1-6	-.22*	-.30*	-.10*	.02	-.11*	.14*	.22*	.07	1.00	
males	3,91	1.61	1-6	- - -	-.36*	-.06	-.04	-.02	.16*	.20*	.07	1.00	
females	3.25	1.30	1-6	- - -	-.22*	-.21*	.04	-.03	.10	.19*	.02	1.00	

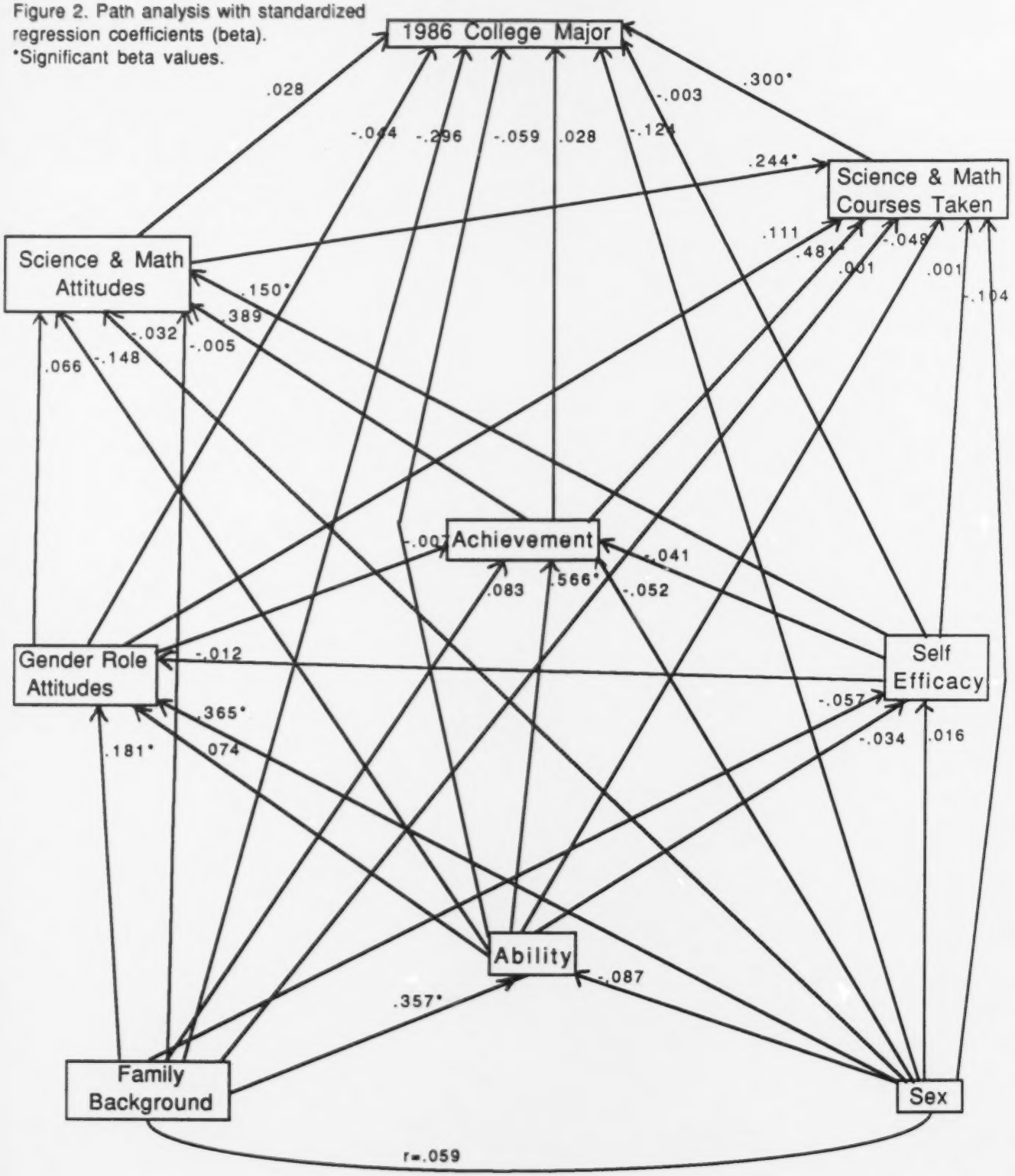
a strong intercorrelation with sex, but only small correlations (rs <.15) with any of the academic or attitudinal variables.

Sex differences were most apparent on the dependent variable, college major. The mean value for males was approximately one half of a standard deviation greater than the mean for females. Other small, but noticeable differences favoring males occurred in the measures of ability, self-efficacy, science and math attitudes, science and math courses, and achievement. The only mean difference favoring females (.4 standard deviations) was the gender role composite.

Figure 2 illustrates the results of the multiple regression procedures. Standardized regression coefficients (β) are marked with an (*) where statistically significant (alpha=.05). The power of multiple regression path analysis procedures are strongly influenced by the amount of inherent variability in variables in the model. The study presented here deals with a very select group: Only those students who have made it through almost four years of college in one of six rigorous programs of study. Therefore, the amount of variability in the dependent measure able to be explained by the independent variables is definitely limited. It is important to note that this study was able to explain 20% ($\underline{R}^2$ = .20) of this reduced variance. The sample size used in this model is much smaller ($\underline{N}$ = 188) than in most studies using the HSB data base, therefore statistically significant values are not the result of using an extremely large sample and, in most cases, can be considered meaningful.

The only statistically significant positive direct effect was from advanced science and math courses to college major. A statistically significant negative direct effect was found from family background (which might be a function of the reduced variability), but family background also

Figure 2. Path analysis with standardized regression coefficients (beta).
*Significant beta values.

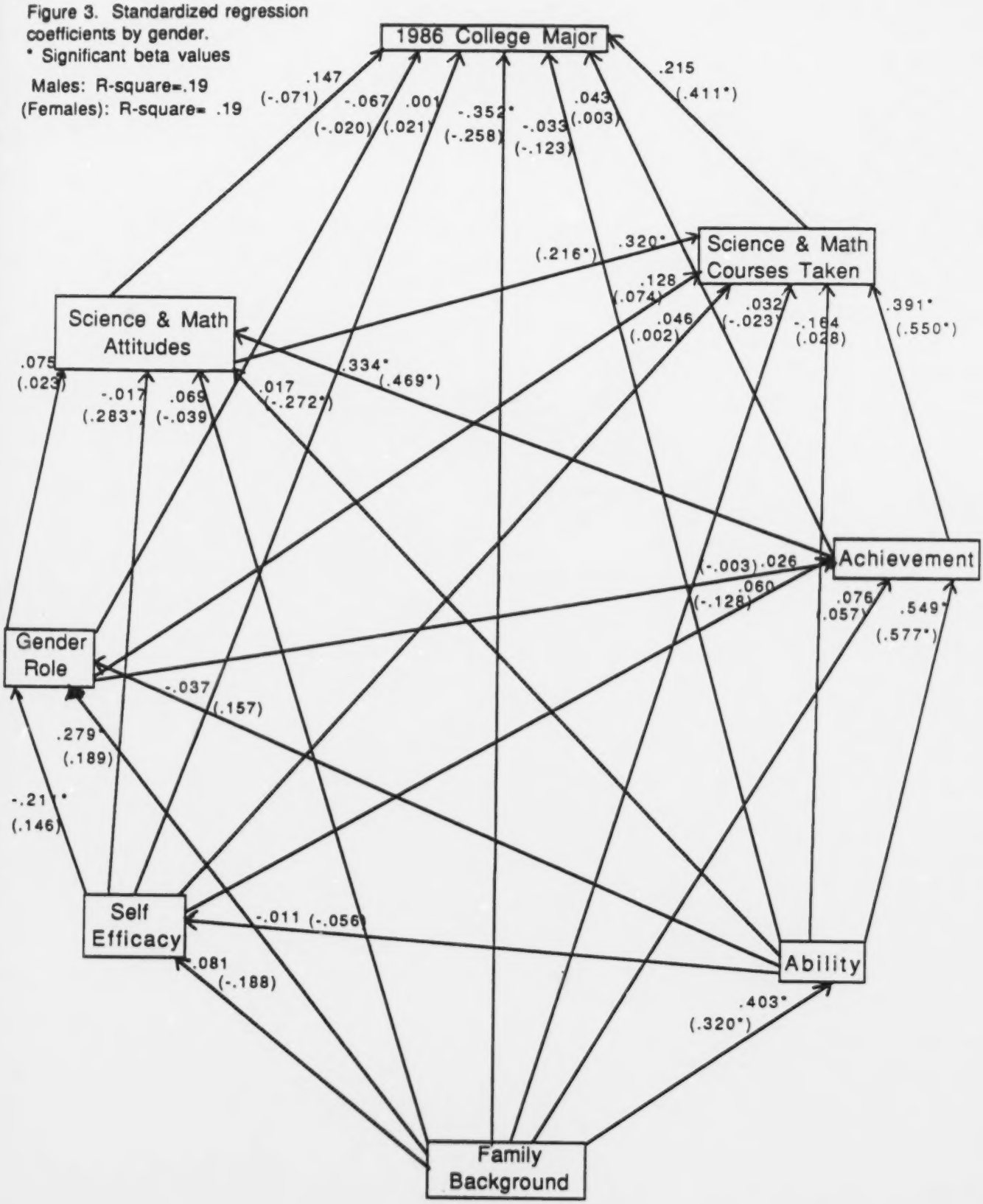


produced a strong positive path through ability, achievement, and science and math courses. The direct effects of achievement and science and math attitudes upon the dependent variable were quite small, but achievement had significant effects upon science and math courses and upon science and math attitudes, while science and math attitudes had a significant positive effect upon advanced courses taken. Self- efficacy produced a significant positive effect upon science and math attitudes, but had little effect upon the dependent variable or on any of the other independent variables. Sex had an insignificant negative direct effect (in favor of males) upon college major, but had little or no effect upon any of the independent variables except gender role perceptions.

Figure 3 points out the differences between males and females on the multiple regression analyses. Males had stronger beta weights along the paths from science and math attitudes to advanced science and math courses and from family background to ability. Males also had a stronger negative path from family background to college major. Several of the independent variables had greater effects for females than for males. The beta weight from the strongest predictor, advanced courses, to college major was .411 for females and .215 for males. The path from achievement to science and math attitudes was stronger for females; .469 for females, and .334 for males. The path from achievement to science and math courses was also stronger for females .550 compared with .391 for males. One of the most interesting sex differences is the effect of self efficacy upon science and math attitudes. Females had a statistically significant path of .283, while males had a slightly negative path of -.017.

Figure 3. Standardized regression coefficients by gender.
* Significant beta values

Males: R-square=.19
(Females): R-square= .19



Discussion

This study confirms Deboer's (1984) work, finding that fewer females enroll in science classes. Deboer focused on college undergraduates, while this study examined the course taking behavior, among other things, of high school students. Males in this study took an average of 0.2 of a standard deviation more advanced science and math courses than females, but the more interesting result of the present research involves the numbers of females making the transition from advanced high school courses to undergraduate technical and physical science majors. With other things being held equal, the progression from advanced high school courses to college science classes favored females, with a beta-value almost twice that of males.

One of the advantages of using the six different categories of science majors instead of a more condensed grouping is that it reveals a more accurate picture of the sex differences of undergraduate science majors. More females than males from the original sample (3.9% compared with 3.7%) elected a college major in one of the six science categories. Many of the sex differences among the categories still fall along traditional lines. Over 50% of the valid sample of men, but only 11.6 % of women were engineering or physical science majors. On the other hand, over 60% of the women involved in the sciences were life science or natural resources majors, while only 25% of the men choose those fields of study. These differences would not have been apparent if a more condensed grouping was used.

Steinkamp and Maehr (1984), found that women have a higher motivational orientation towards biology than men, but the opposite is true for physical sciences. The distribution of college science majors reported here is what one would expect based on Steinkamp and Maehr's (1984) work with motivation: females were more prevalent in life science majors, while men continued to

dominate the physical and technical sciences. Steinkamp and Maehr (1984) concluded that girls attitudes toward science appear to differ from their attitudes towards careers in science; causing them to be under-represented in science classes, and as college science majors. In the present study, as many women as men were college science majors, but the choice of specific major still showed noticeable sex differences. While these students were in high school though, the results of this study agreed with the conclusions reported by Steinkamp and Maehr (1984); given similar science attitudes, more boys than girls will enroll in advanced high school science classes. This can be seen be the lower beta value for females on the path from science attitudes to advanced classes.

These facts, though, do not support the expectations of Steinkamp and Maehr that fewer females will pursue programs of study in science. An advanced degree program and/or career in biology is as difficult to combine with family responsibilities as is a career in physics. The common reason that fewer numbers of females pursue physical science careers due to family responsibilities, does not seem to explain their increased enrollment in biology and psychology programs. There are obviously other variables coming to play in this decision.

Handley and Morse (1984) concluded that gender role self-concepts are related to attitudes about science, and that the relationship between science attitudes and gender role perceptions become more pronounced as girls progress through adolescence. Steinkamp and Maehr (1984) reported that a variable they called "dimension of motivational orientation", accounted for significant portions of the effect size variance in the articles and large-scale samples. This variable is closely related to parts of the gender role and the science attitudes variables used in the present study. Steinkamp and

Maehr (1984) speculate that many girls who like science consider science occupations too demanding to combine with family responsibility.

The present study showed that gender role had very little effect on science attitudes, advanced science courses taken, or on choice of college major. Self-efficacy, on the other hand, had a significant influence on female's science and math attitudes, and a slightly positive effect on gender roles. Handley and Morse (1984) were working with middle school and high school students, while this study concentrated on those students who actually became college science majors. The females involved in my study were already part of a select group, 3.9% of the sample, and it is likely that their gender role perceptions are above the general population norm. This important area is deserving of more research attention in the future.

One of the major strengths of this path model is its ability to predict for advanced science and math course taking behavior, particularly among females. In the model with advanced courses as the dependent measure, the independent variables accounted for over 43% of the variability for females, and approximately 32% for males. Similar percentages of variability were accounted for when achievement was the dependent measure.

It was more difficult to account for the variability when dealing with the affective independent variables, such as science and math attitudes, gender role perceptions, and self-efficacy. This is one of the problems with adapting previously gathered, large-scale data sets to one's research questions. However, as long as these limitations are understood, the advantages of being able to sample large percentages of the population are quite clear.

While noticeable gender differences did emerge in this study, there was a very small direct effect of gender on the dependent measure of science

major. Many of the strong paths showed similar results for both sexes such as those from family background through ability, achievement, advanced courses, to college major, separating the analysis by sex helped to point out some interesting path differences. The most interesting difference involved the path for females from self-efficacy through science and math attitudes to advanced courses and then on to college major. This same path was virtually absent for males.

This study has some important implications for science educators and school officials. By working to improve the self-efficacy of female students, it is likely that their science and math attitudes will improve. With these improved attitudes and proper encouragement, more females will enroll in advanced science and math courses and continue on to pursue physical and technical science majors, thereby eliminating the gender gap in science careers.

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